EYE TRACKING METHOD AND SYSTEM AND INTEGRATION OF THE SAME WITH WEARABLE HEADS-UP DISPLAYS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 62/754,307, filed 1 Nov. 2018, titled "Eye Tracking Method and System and Integration of the Same with Wearable Heads-Up Displays", the content of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The disclosure relates to methods and systems for tracking a gaze position of an eye in a target space, such as a display space formed by a wearable heads-up display.

BACKGROUND

Eye tracking is a process by which one or more of a position, orientation, and motion of an eye may be measured or monitored. In many applications, this is done with a view towards determining the gaze direction of a user. There are various eye tracking techniques, the least invasive of which employs one or more optical sensors, e.g., cameras, to optically track the eye. Common techniques involve illuminating or flooding the eye with infrared light and measuring reflections from the eye with at least one optical sensor that is tuned to be sensitive to the infrared light. Reflections of infrared light from the eye are analyzed to determine the position, orientation, and/or motion of one or more eye features, such as the cornea, pupil, iris, and/or retinal blood vessels.

Eye tracking may be implemented in near-eye or head-mounted devices that have a structure to deliver light to the eye. One example of such near-eye or head-mounted devices is a wearable heads-up display that can be worn on the head like conventional glasses. In wearable heads-up displays, eye tracking can enable a variety of functionalities, such as influencing where content is displayed in the field of view of the user, conserving power by not displaying content that is outside of the field of view of the user, influencing what content is displayed to the user, determining where the user is looking or gazing, determining whether the user is looking at displayed content on the display or at scenes in the external environment, and providing an interface through which the user may control or interact with displayed content.

Eye tracking functionality if incorporated into a wearable heads-up display will need to be robust enough to accommodate movements of the wearable heads-up display and/or head of the user wearing the wearable heads-up display. Without the necessary robustness, movements of the wearable heads-up display and/or head of the user during eye tracking can lead to errors or inconsistencies in the gaze positions obtained from eye tracking. Some eye tracking systems use multiple cameras and some method of fusing the data from the multiple cameras to improve robustness of eye tracking. However, there are challenges with incorporating multiple cameras into a wearable heads-up display due to space constraints in the wearable heads-up display and/or other design requirements of the wearable heads-up display.

SUMMARY

In a first aspect, a method of tracking a gaze position of an eye in a target space in a field of view of the eye over an

eye tracking period may be summarized as including performing a plurality of scans of the eye with infrared light within the eye tracking period; detecting reflections of the infrared light from the eye for each scan; and determining the gaze position of the eye in the target space from the detected reflections of the infrared light signals for each scan, where each scan includes generating infrared light over a scan period and projecting the infrared light signals from a number M>1 of virtual light projectors to the eye to form the number M of illumination areas on the eye.

The method according to the first aspect may further include one or more of the features described in A1 to A18 below.

A1: Projecting the infrared light signals from the number M of virtual light projectors to the eye to form the number M of illumination areas on the eye includes directing the infrared light signals from a source of the infrared light signals to an optical scanner over the scan period while controlling the optical scanner through a range of scan positions to deflect each infrared light signal at a respective scan angle.

A2: Projecting the infrared light signals from the number M of virtual light projectors to the eye as described in A1 further includes receiving each infrared light signal deflected by the optical scanner at one of the number M of optical elements of an optical splitter, and where during at least a portion of the scan period each of the number M of optical elements receives a subset of the infrared light signals and redirects each subset of the infrared light signals in a respective direction.

A3: Projecting the infrared light signals from the number M of virtual light projectors to the eye as described in A2 further includes receiving each subset of the infrared light signals redirected by each of the number M of optical elements at an optical combiner and redirecting each subset of the infrared light signals by the optical combiner to the eye, thereby forming the respective illumination area.

A4: An optical function is applied to at least a portion of the infrared light signals redirected by at least one of the number M of optical elements and received by the optical combiner. Applying an optical function to at least a portion of infrared light signals may include applying a beam diverging function to the at least a portion of the infrared light signals. Alternatively, applying an optical function to at least a portion of the infrared light signals may include applying a beam converging function to the at least a portion of the infrared light signals.

A5: Determining the gaze position of the eye in the target space from the detected reflections of the infrared light signals for each scan includes (i) identifying a plurality of glints from the detected reflections of the infrared light signals for the scan, each glint having a glint center position in a scan space, (ii) determining the glint center position in the scan space for each of the plurality of glints, and (iii) determining the gaze position relative to the target space based on the glint center positions.

A6: Determining the gaze position relative to the target space based on the glint center positions as described in A5 includes (i) applying a mapping function that transforms coordinates from the scan space to the target space to each of the glint center positions to obtain a corresponding intermediate gaze position in the target space, and (ii) combining the intermediate gaze positions to obtain the gaze position in the target space for the scan.

A7: At a select recalibration time during the eye tracking period, the mapping function of A6 is adjusted to compensate for drifts in the scan space relative to the target space.